60W Nanosecond Pulsed All-Fiber Laser Amplifier for Bulk and Thin Film Material Modification

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Fiber lasers have the advantage of high beam quality, high efficiency, small size, and air cooling. Therefore much interest in the development of high power fiber laser systems has recently arisen in the world [1]. Almost all commercially developed fiber lasers with nanosecond pulse duration that are being used for material processing are Q-switched systems. Vital parameters in the material processing, such as repetition rate, pulse energy and pulse duration, are correlated with each other and hence cannot be adjusted independently in the Q-switch mechanism. For high beam quality pulse energy better be 0.5-1.0 mJ and as the repetition rate determines the processing speed, aiming for high average power leads to best results [2]. As a result, development of all-fiber laser systems with diffraction limited beam quality, high energy, high repetition rate at high average power, and independently adjustable parameters are highly desired.

In this study, ytterbium doped all-fiber laser amplifier with 60 W average power and more than 20 kW peak power at 1 µm wavelength was developed. This master-oscillator power-amplifier (MOPA) architecture system is composed of pulses, produced by electronically pumped diode, and amplified by a series of fiber amplifiers [3]. Apart from Q-switch lasers, MOPA architecture allows us to adjust pulse duration, repetition rate and power independently. Beam quality is nearly diffraction limited, and typically the value is $M^2<1.3$.

Produced by 1064 nm wavelength laser diode, the pulses with the approximate duration of 200 ns or longer are amplified to 3 W average power by a middle amplifier and then to 60W average power by an amplifier stage. The maximum pulse energy achieved 0.6 mJ at 100 kHz repetition rate and minimum pulse duration is ~30 ns at this energy level. System is all-fiber and the amplified laser output is delivered from the collimated isolator following the 2 m long beam delivery fiber. Due to multi-stage architecture and special precautions, the system works without ASE (<1%) and shows an optical efficiency of 64% Because of Raman scattering, peak power value is limited to 20 kW for the current beam delivery fiber lengths. This value can be increased if the beam delivery fiber length will be shorter or in the applications where transfer of more energy to stokes wavelengths won’t be a problem. Additionally, due to MOPA architecture, the fluctuations (energy changes between pulses and the energy changes during a single pulse) are fewer than the systems which are using Q-switch. In material processing, high stability and high beam quality leads to high consistency. Reduced diameters of active and passive fiber cores and specially optimized fiber splices, which are used in the system architecture, results with higher beam quality thus the focusing is better than commercial lasers. As the thing which determines the interaction with materials is the power delivered to target area (intensity), with this system the material is processed effectively with less power.

References

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